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PULSED MAGNETIC FIELD FERROMAGNETIC MICROWAVE GENERATOR

Quarterly Report

By
L.D. Buchmiller--F.A. Olson

January 1968

ECOM

UNITED STATES ARMY ELECTRONICS COMMAND · FORT MONMOUTH, N.J.

Contract No. DAAB07-67-C-0215

MICROWAVE ELECTRONICS, A Division of Teledyne, Inc.
Palo Alto, California 94304

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January 1968

PULSED MAGNETIC FIELD FERROMAGNETIC MICROWAVE GENERATOR

Third Quarterly Progress Report
1 July 1967 to 30 September 1967
Report No. 3

Contract No. DAAB07-67-C-0215
DA Project No. 1H6-22001-A-055-05-06

Object

To develop a microwave nanosecond pulse generator using ferrimagnetic materials subjected to pulsed magnetic fields.

Prepared By
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MICROWAVE ELECTRONICS
Palo Alto, California

For

U.S. Army Electronics Command, Fort Monmouth, N.J. 07703

ABSTRACT

Measurements on the voltage-triggered spark gap show that excessive jitter is caused at high pulse repetition rates by the interaction of the trigger and pulser circuitry. Ultra-violet (U-V) triggered gaps will be used to minimize this interaction problem.

A new method has been devised for obtaining increased power output using multiple YIG spheres in a distributed circuit configuration.

A radial line transition between a 4-ohm coaxial line pulser and the pulsed field coil has been designed to decrease pulse risetime degradation at this transition.

Preliminary measurements on a U-V triggered spark gap installed in a 4-ohm coaxial line pulser indicate fast risetime pulses are feasible.

CONTENTS

ILLUSTRATIONS

PURPOSE

The purpose of this program is to determine the feasibility of a microwave generator in which a ferrite material is used to convert energy from a pulsed magnetic field into coherent energy.

The investigation includes studies of generator performance features and limitations, and the fabrication of an exploratory developmental model to demonstrate microwave generation of X-band power at nanosecond pulse widths by the use of a ferrimagnetic material immersed in a pulsed magnetic field. The design objectives are as follows:

RF Pulse Width	1 to 3 nanoseconds
Center Frequency	9.6 GHz
Frequency Tuning Range	9.6 GHz ± 4 percent
Peak Power	2 kW
Pulse Repetition Rate	1 to 10 KHz

The unit is to be self-contained, including pulsing circuitry with only applied dc voltages required. Maximum overall efficiency, reliability, life and simplicity of operation are desired characteristics.

PUBLICATIONS, LECTURES, REPORTS AND CONFERENCES

There were, during the first quarter, no publications, lectures or reports resulting from research carried on under this contract. A conference was held on 20 July 1967, with Mr. John Carter of USAEC to review current work to determine the direction of future efforts.

A meeting with Dr. H.J. Shaw of Stanford University and Stanford Research Institute personnel, L. Young and A. Karp, was held on 13 September 1967.

FACTUAL DATA

I. INTRODUCTION

A microstrip line pulser design using a rutile dielectric material is described in Section II.

A radial line transition from a coaxial-line pulser to the pulsed-field coil designed to improve pulse risetime is described in Section III.

Measurements on the voltage-triggered and U-V spark gap switches are described in Section IV. Work on two aspects of multiple YIG sphere operation for increased power output are discussed in Section V. The two aspects are:

(1) Measurements on two coils connected for series and parallel operation.

(2) A new method of connecting coils in series employing a distributed circuit approach.

II. HIGH DIELECTRIC CONSTANT MICROSTRIP LINES

High dielectric constant microstrip lines are being considered for construction of a pulse current generator of reduced size. A material that appears suitable[1] is temperature-compensated rutile, manufactured by the American Lava Company, and available with dielectric constants up to 87 ±9.

An important consideration in designing the pulse generator is risetime degradation due to the decrease in width of the microstrip line which is necessary in connecting the microstrip line to the narrower pulsed field coil. This effect will hereafter be referred to as the "necking down" problem and results from differing current path lengths as shown in Fig. 1. The delay of current arriving at the coil from Path 2 relative to that from Path 1 results in a risetime degradation equal to the delay. Assuming Path 2 is longer than Path 1 by approximately one-half the strip-line width of width 2a, then the risetime degradation will be given by $T_d = a/v$
where v is the velocity in the microstrip line.

In the Stanford pulse generator the half width "a" is one inch and the velocity for the Mylar dielectric used is 6.7 inch/ns so that the risetime degradation is 0.15 ns.

For the case of rutile dielectric material with a relative dielectric constant, k, of 81, the half width "a" is approximately 0.2 inch for $T_d = 0.15$ ns assuming v is given by $c/\sqrt{k}$ where c is the velocity of light. The dielectric thickness required for a characteristic impedance of 7 ohms as calculated using Wheeler's[2] equations is 0.080 inch. This thickness is too small for a 20-kV pulser since the dielectric strength is 150 V/mil for a 0.050-inch thickness. Greater line thicknesses and widths must then be used with a further increase in pulse risetime degradation. Other high-k dielectric materials will be investigated both for microstrip and coaxial line configurations.

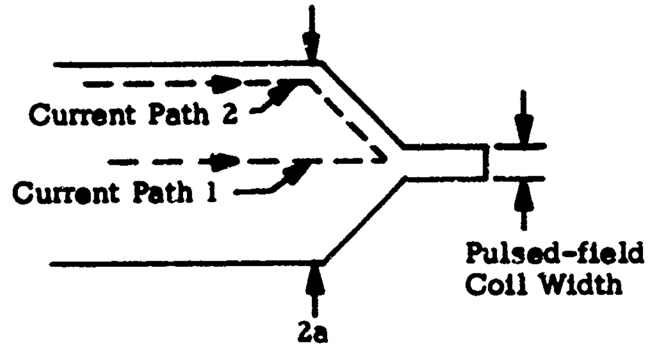

Fig. 1. Schematic illustrating the "necking down" problem for microstrip line pulsers.

III. RADIAL TRANSMISSION LINE TRANSITIONS

The pulse risetime degradation due to the "necking down" problem using microstrip lines was described in Section II. A similar consideration of coaxial-line construction shows that the risetime degradation will be minimized due to the symmetry of the coaxial-line construction. A method of connecting the pulsed-field coil to the coaxial-line pulser using a radial-line transition is shown in Fig. 2. A radial 4-ohm line transition has been designed[3] for the 4-ohm coaxial line which was constructed during this reporting period.

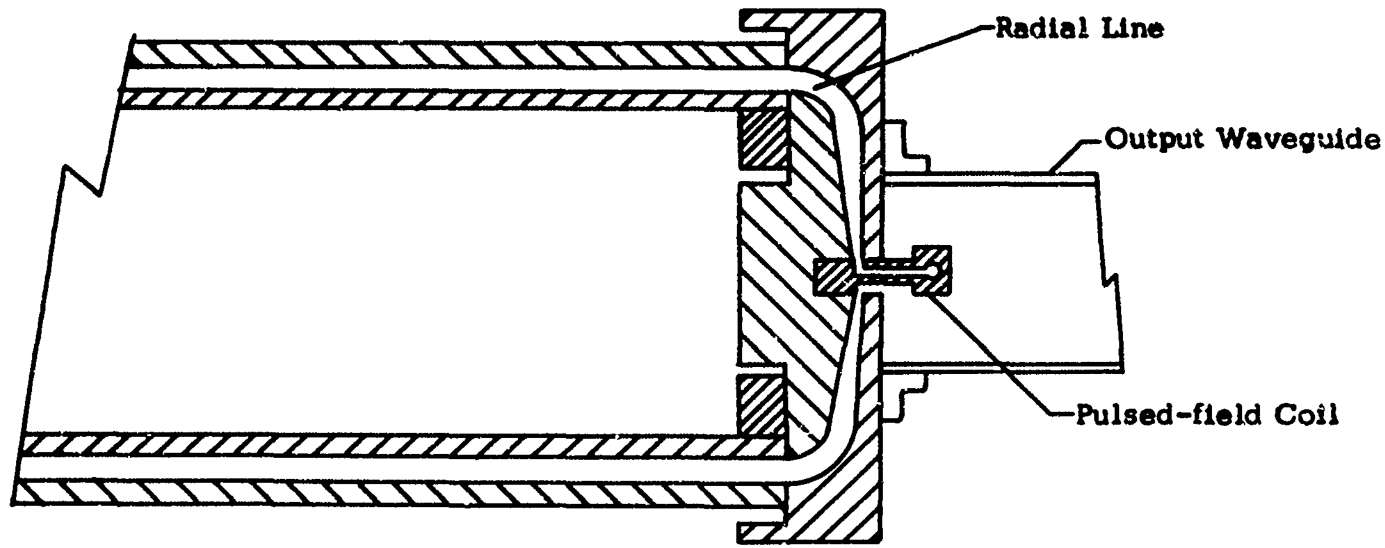

Fig. 2. Schematic of the radial-line transition from a coaxial-line pulser to the pulsed-field coil.

IV. TRIGGERED SPARK GAP PULSERS

Tests of the ITT voltage-triggered spark gap switch were performed in the 4-ohm coaxial line configuration described last quarter. The ITT TT-81 trigger transformer proved to be underdesigned for the 200 cycles/sec pulse repetition test frequencies used, and resulted in high-voltage breakdown to the transformer core. The trigger circuit was then revised by replacing the ITT pulse transformer with a 6-volt Ford spark coil. Strong interaction between the trigger circuitry and the main pulse circuitry resulting in bad jitter was noted in both cases. This interaction also caused extraneous radiation which made scope triggering difficult. Further efforts were then directed to the use of U-V triggering where this interaction is minimized.

The U-V triggered spark gap switch described last quarter was installed in a 4-ohm, 2-ns pulser, coaxial-line configuration shown schematically in Fig. 3. The gap widths of both the main and the sharpening gaps are adjustable externally. The OD of the inner conductor is 2 inches while the ID of the outer conductor is 2.25 inches. Rolled 10-mil sheet Mylar is used as the dielectric insulation material. Unfortunately, cracks in the glass-to-kovar seal appeared and high-voltage arcing occurred between the trigger leads and the center conductor of the pulse-forming line. Tests were then performed with self-breakdown of the main pulser gap as in the Stanford pulser. The pulse shape as observed before the sharpening gap is shown in Fig. 4 and indicates that the 4-ohm coaxial line configuration will be satisfactory.

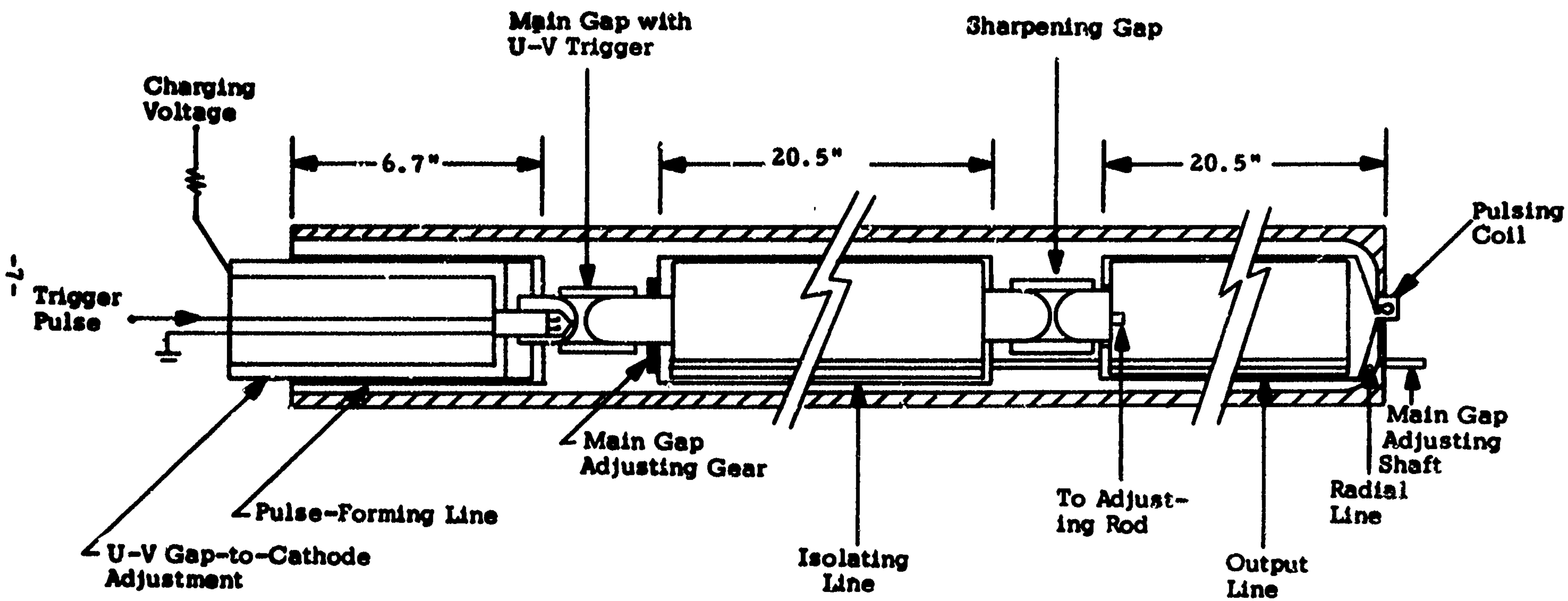

Fig. 3. Schematic of the 2-ns 4-ohm coaxial line-pulser with U-V triggering and a radial-line transition to the pulsing coil.

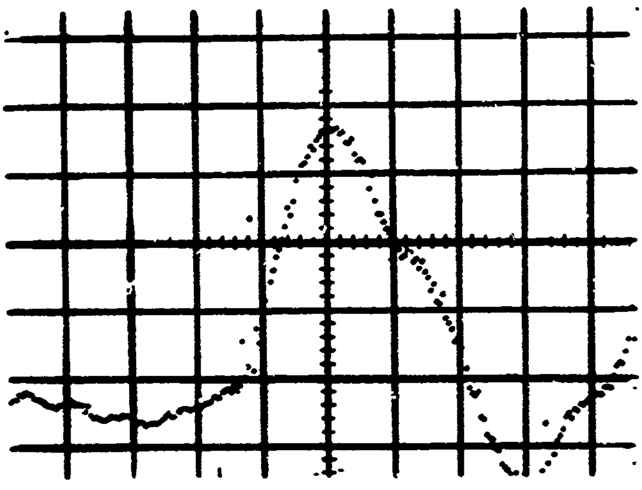

Fig. 4. Unsharpened voltage pulse of the 4-ohm coaxial line-pulser. The horizontal scale is 2 ns/div. The vertical scale is approximately 1.5 kV/div. The corresponding pulse current is 1500 amperes.

V. MULTIPLE-SPHERE OPERATION

RF cold test measurements were performed with the two-coil series and parallel pulsed-field coil configurations shown in Fig. 6 and 7 of QPR No. 2. The series coil configuration as shown is unsatisfactory since the connecting bar between the two coils acts as an antenna and radiates RF energy to the pulser line. The parallel configuration appears feasible although some spurious mode difficulties have been encountered. This parallel configuration will be tested with the 4-ohm coaxial line pulser with U-V triggering.

A serious disadvantage of the parallel coil operation described above is that the pulsed current required becomes excessive for multiple-sphere operation.

A new scheme that allows series coil operation in a distributed interaction approach has been devised. A possible physical realization of this scheme is shown in Fig. 5. In this approach the multiple pulsed-field coils form the inductive part of a periodic circuit similar to an artificial transmission line. The RF coupling from each YIG sphere to each waveguide is identical with that currently used in the Stanford pulser. The RF outputs from these guides must be added together in an RF-combining circuit. The phase velocity of the pulser current and the RF phase velocity in the combining circuit will have to be adjusted so that the RF outputs combine for maximum power output.

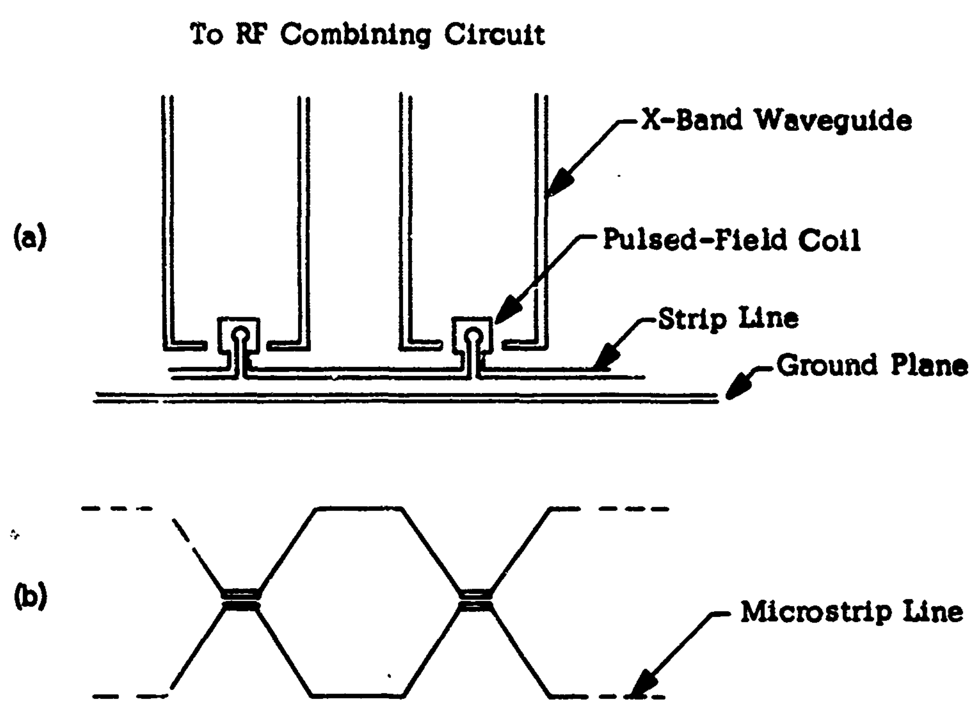

Fig. 5. Schematic of multiple-sphere distributed circuit configuration. (a) side view; (b) top view of microstrip line.

CONCLUSIONS

Experiments indicate severe interaction problems occur with voltage-triggered gaps at high pulse-repetition rates so that further work will be concentrated on U-V triggering.

Preliminary measurements and a radial-line transition design on the 4-ohm coaxial line pulser indicate this configuration will be satisfactory.

Increased RF power output with no increase in pulser capability now appears feasible using a new method of multiple YIG operation in a distributed interaction approach.

FUTURE WORK

Future work will include:

(1) U-V triggering in a 4-ohm coaxial line pulser employing a radial line transition to the pulsed-field coil.

(2) Designing components of the multiple-sphere distributed interaction approach.

(3) Further investigation and design of pulser miniaturization employing high dielectric materials.

(4) Completing a feasibility study of high current solid-state switches.

IDENTIFICATION OF KEY TECHNICAL PERSONNEL

Key technical personnel and respective man-hours devoted to the contract during this reporting period are listed below.

L.D. Buchmiller, Senior Research Engineer	163 hours
W. Mitchell, Research Technician	318 hours

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2. H.A. Wheeler, "Transmission-Line Properties of Parallel Strips Separated by a Dielectric Sheet", IEEE Trans. on MTT, pp 172-185, March 1965.

3. S. Ramo and J.R. Whinnery, "Fields and Waves in Modern Radio", 2nd Ed., pp. 395-401, John Wiley and Sons, Inc., New York, N.Y.

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